

## CAD/CAM In Metal Ship And Boat Building

Chris Barry

IBEX 2002  
Session 505  
9:00 AM February 8, 2002.

## Introduction

- Case Histories
- Eight Keys To CAD/CAM
- Examples
  - Simple Standardization
  - Total Process Re-Invention
- Software Implementation



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## CAD/CAM Is A New Paradigm

- The Naval Architect's First Keystrokes – Directly To Production - Via CAD/CAM
- Requires Cross Functional Changes
- Why ? – **Show Me The Money !**
  - \$ Improved Productivity
  - \$ Reduced Schedule
  - \$ More Accurate Bidding
  - \$ Level Workforce
  - \$ Improved Quality – Reduced Rework
  - \$ Weight / Cost / Process Control
  - \$ More Jobs - More Throughput – More Profit

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## Munson: 2D Structural CAD/CAM



- Standardized/Parametric Hull Design
- Integrated CAD, Hydrostatics
- Standardized Systems
- Wire Transfer CNC Data to Cutting Service
- Delivery Times Reduced
- Gross And Profits Tripled

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## Coast Guard YARD: Re-Engineering With CAD/CAM

- Hybrid 2D/3D System
- Improved Weight Control
- ISO 9001/Baldrige Certified Process
- Used TQM Tools
- Integrated Across Production And Design
- Boats Built On Time, Below Budget

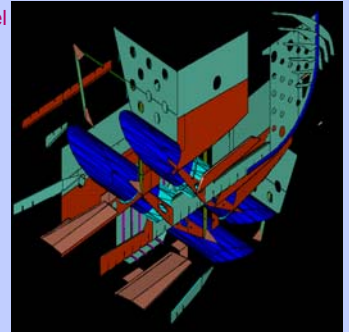


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## Bender: Full 3D Product Model

- Full 3D Product Model
- Desktop / AutoCAD Based System
- Structure - ShipCAM
- Piping - Rebis
- Automated Solids
- Same Design Costs
- **Reduced Construction Cost 20+% On 1st Boat**



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## Eight Keys to CAD/CAM

From: Barry, Oetter, Lane & Mercier,  
"Keys To CAD/CAM In Small Shipyards",  
1998 SNAME Annual Meeting, San Diego CA

- Process Re-engineering
- The Integrated Product Model,
- Design for NCC Production,
- Advanced Outfitting/group Technology,
- A Flexible Standard Product Line,
- Concurrent Engineering,
- Advanced Workflow Control
- Statistical Process Measurement and Control

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## Process Re-Engineering

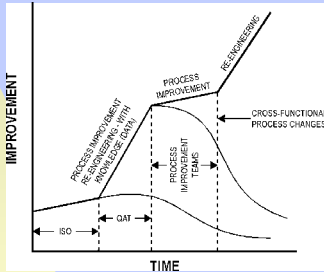
*"Engineers and Designers Need to Gain Profound Knowledge of the Erection Process and Incorporate Product Design and Process Design Producibility Features into the Detail Design."*  
Deming

- The Most Important Aspect of CAD/CAM
- Develop Profound Knowledge of Processes and Their Relationships
- ISO/Baldrige - More Than a Paper Chase
  - Documenting Current Processes Gains **Profound Knowledge**
- Customer Focus - Team Building
- Use Formal TQM Tools

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## Continuous Improvement



- The Act Of Improving Gains Profound Knowledge - Allowing More Improvement

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## Designers

*"Being careful isn't nice - being friends is better"*  
*A Bargain For Frances, Hoban & Hoban*

- Designers Need Profound Knowledge
- Cooperation - Alignment
- Long Term Relationships
- Profit Sharing Between Design Agents/Shipyards
- Owner/Builder Construction-

### The Virtual Shipyard

- Tugs/Fishboats Larger Than 100'
- A New Market For Design Agents

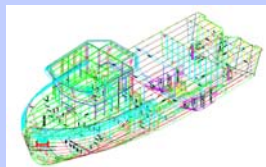
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## The Integrated Product Model

*"Make it 300 Cubits ..."*  
*Early Ship Preliminary Specification*

- The Electronic Admiralty Model
  - Three Dimensionality
  - Linked Databases
    - AutoCAD ASE
- Customize For Value Added
  - Use Symbology, Attributes
  - Use Customer Focus To Determine Features
  - Software Tools Are Constantly Changing



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## Design For NCC Production

*"The second cut is free"*

*Steel service salesperson*

- Fiduciary Marks
- Cut Instead of Forming
  - Flat Plat Longs (With Bulbs?)
- Poke Yoke - Foolproof Assembly
  - Notches, Tabs, Tools, Jigs
  - Align With Shops
  - Cheap To Cut Tools/Jigs With CAD/CAM
- Alternative Processes -
  - Free-Forming
  - Origami Boats



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## Advanced Outfitting Group Technology

*"Outfit Always Eats Our Lunch"*

*Bill Munson*

- Build It Outside The Boat
  - Each Building Stage Increases Labor
  - Requires 3D Product Model
  - Location/Timing/Integration
- Group Technology Requires Part Classification
  - Group Like Parts By Process
  - Reduce Part Count
  - Fuzzy Logic For Parts Classification
- Allows Comparisons Of Like Tasks

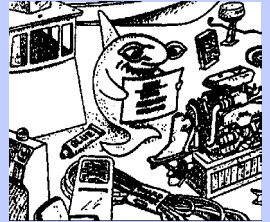


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## Flexible Standard Product Line

- Standard Parts/Custom Boats
  - Pricing Advantages
- Structure Is Easy, (CAD/CAM) Outfit Is Hard - Standardize As Much As Possible
- 80% Of Design Effort Is Just Getting Component Data
- Parameterized Systems
- Buy Standard Parts
- Automated, Accurate Bidding
- Requires Group Technology



*"Some Assembly Required"*

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## Concurrent Engineering

- 3 D Product Model
  - Primary Means of Communication
  - Gets Production Concerns In As Early As Possible
  - Helps Visualize Entire Problem
- Right Of Way
  - No More "First In Gets The Space"
  - Rational Space Allotment/Coordinated Placement
  - Guaranteed Spaces
  - Tighter Placement
  - Radically Reduces Interferences - And Interference Control Effort
  - Possible At Early Design Stage

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## Advanced Workflow Control

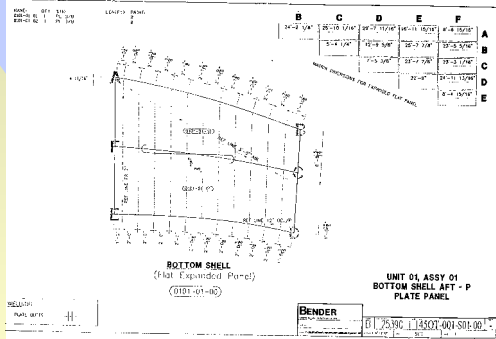
- Kan Ban - Signal Card
  - Pull - Through System, Very Simple To Implement
  - Reduces Planning and Tracking
  - Self-Pacing Work
    - Reduced Workforce Waiting
    - Incentivised/Entrepreneurial Workforce
- Assembly Trees
  - Works With Fiducials/Poka Yoke
  - Reduced Drafting Effort
  - 3D Exploded Assemblies (From Product Model)
  - Quality Control Dimensions



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## Work Assembly Drawings

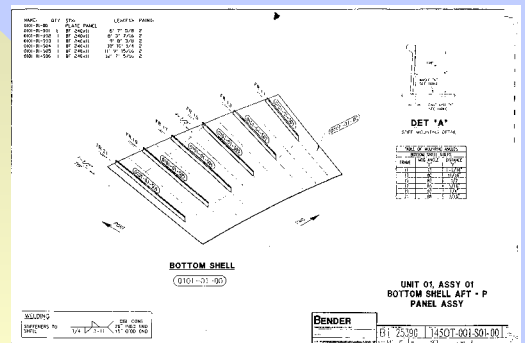


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Courtesy Bender Shipbuilding

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## Work Assembly Drawings

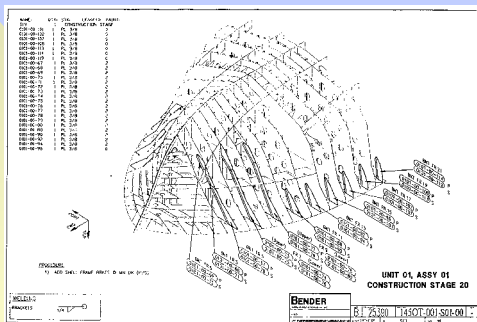


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## Work Assembly Drawings

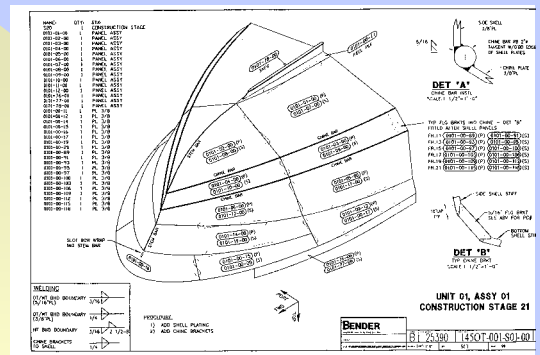


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## Work Assembly Drawings



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## Statistical Process Measurement And Control

- Improve Processes, Improve Bidding
- Product Model Contains Rich Information
  - Weld Lengths, Perimeters, Etc.
- Requires Group Classification
  - Compare Like Process, Products
  - Distinguish Between Making Easier Products And Making Them Faster
- Involve Workforce In Measurement
- Key Off Quality Control Dimensions

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## Simple Standardization Example

- Reinforcing Ring
  - Buy Special Bender?
  - Re-Engineering Process
  - Standardize With Group Technology
  - Make Or Buy ?
  - Integrate With Outfit Process



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## Total Process Re-Invention: Optimized Construction Of Developable Surface Boats With CAD / CAM

From  
"Block Construction of Small Ships and Boats  
Through Use of Developable Panels"  
By  
Rolf Oetter, Christopher D. Barry, Bryan Duffy  
and Joel Welter  
2001 SNAME Ship Production Symposium  
Ypsilanti, Michigan, June 13 –15 2001

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## Goals

- Maximize Shop Work / Minimize "Stick Building"
- Maximize Use of CNC Components / Minimize Hand Cutting - Improve Fit-Up Quality
- Maximize Down-Hand / Automated Welding
  - Better Quality, Less Distortion, Happier Workers
- Maximize Advanced Outfitting
  - Easier Access, Reduced Cost
- Level Man Loading – Reduce Layoffs
- Minimize Special Equipment Cost
- Minimize Coating / Prep Cost
- Minimize Fit-up Problems & Re-Work

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## Developed From “Free Forming”

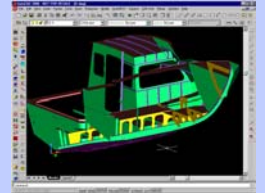
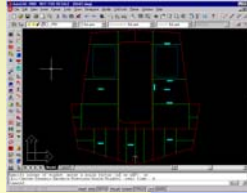
- Well Established Technique in Pacific NW
- Eliminates Lofting
  - Boats Built “Close Enough” From Models
  - Built From Shell Plate In - All Work Templated
  - Uses a “Deadrise Jig”
  - Guarantees Fair Hull, But Uncontrolled Shape
- NW Yards Jumped Directly Into CAL/NCC
  - Yards Still Build In From Shell
  - Many Use CNC Cut Jigs

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## Victoria Ship Yards

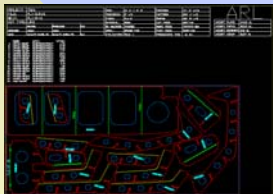
- Modified Technique Used
- Bottom Plate Welded Together Aft to Front.
- Shape Self Determining to Match Nc-routed Frames.



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## Victoria Ship Yards



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## Proposed Process

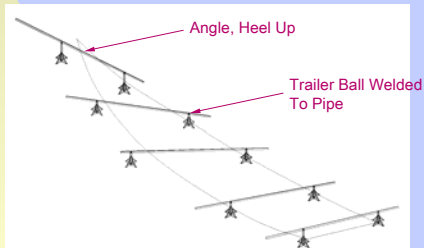
- Precut Parts - (CAL/NCC)
- Subdivide Into Panel Blocks
- Make Up Plate On Ruling Jig
- Install Longs, Web Frames
- Install Foundations, Brackets
- Blast, Prime, Finish Paint, Mount Outfit
- Join Bottom Panels, Outfit Some More
  - Add Deck, Outfit, Add House, Etc.

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## Ruling Jig

- Surface Rulings Derived From 3D Model
- Angles Set On Rulings Of Surface, Heel Up
- Jackstands Support Angles



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## Developable Surfaces

- Review Basics Of Developable Surfaces
  - Email Me ([cdbarry@hotmail.com](mailto:cdbarry@hotmail.com)) For An Article
- Computers Can't Do It Alone
  - May Find Surface You Don't Want
  - May Be Developable, But Not Fair
  - An Open Ended Hull Forces Straight Rulings
- Use "Old" Hand Techniques - In 3D CAD
  - Rabl's Conic and Multi-Conic Methods
  - Kilgore's Technique (Using UCS In ACAD)
  - Split Surfaces On Desired Rulings
- Use Software Controls

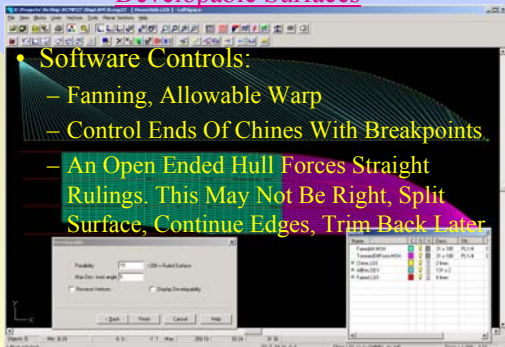
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## Developable Surfaces

### Software Controls:

- Fanning, Allowable Warp
- Control Ends Of Chines With Breakpoints
- An Open Ended Hull Forces Straight Rulings. This May Not Be Right, Split Surface, Continue Edges, Trim Back Later

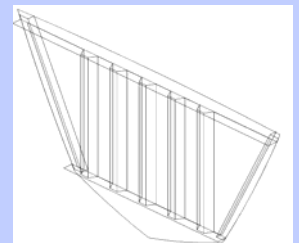


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## Structural Details

- Longs Cut or Formed To "Hard Way" Curve
  - Build Up Bulb Tees For Z, Buckling Concerns
- Transverses With "Natural" Joints
- Penetrations Created By Assembly
- Corrugated Bulkheads
- Alignment Clips - "Poka Yoke" CNC Cut Into Parts (Especially Longs)
- Use Mushroom Brackets To Align/Control Angles, Tees, Adequate Sheer



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## Welding / Coating

- Welding Mostly Down hand
  - Welding Automation Easy
  - Weld Pacers - Simple, Cheap, No Programming
- Coating Easy
  - Easy Access To All Surfaces
  - Easy Grit Removal
  - Controlled Environmental Conditions
  - Good Ventilation - Worker Protection
- A Natural With Aluminum
  - No Interior Coating

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## Advanced Outfit

- Advanced Outfit Rare in Small Ships
  - Blocks Too Small
  - Too Much Engineering Effort
  - Components Too Late
  - Financing Considerations
- Blocks Completely Open, Many In Shop
- Easy 3D CAD/CAM Reduces Engineering
- Man Loading Improved
- Mock Equipment
  - Allows Field Run Pipe, Wire, Late Delivery

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## Software/Hardware Selection

- Cost Of Ownership
  - Hardware/Software
  - Training Costs
  - Lost Productivity
  - Implementation, Customization And Support
- Decide What You Need - Re-Engineer
- Select Software - Re-Engineer Again
- Re-Engineer As Software Changes
- The Worst CAD Product Well-Implemented Is Better Than The Best Poorly Done

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## Software Decisions

- Integrated System Vs Desktop Systems
- Integrated Systems Are Turnkey
- Hardware, OS, No Longer An Issue
- AutoCAD Type Solutions - Roll Your Own
  - Lower Software Costs - Freeware, Cheapware
  - Mixed Seats Reduce Costs
  - General Training/Personnel Readily Available
  - Requires 3rd Party Add-Ins
    - Hull Definition/Lofting Package Required
    - Nesting / Code Generation Required (If Cutting Yourself)
    - Part Database Management Required
    - Specialized Structure Package Highly Advised
    - Specialized Piping Package Highly Advised
    - Project Management Interface Highly Advised
  - Customization Required - Tailoring Easy

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## Software Requirements

- Excellent Control Of Developable Surfaces
- Good 3D Modeling Capability
  - Structural Modeling with Relational Database
  - Piping, Outfit Modeling Built In Or Good Links To Other Software
- Ability To Level Plates, Blocks
  - Pin Jig Option
- Excellent Control Of Plate Expansion
  - Line Heating / Forming Data – Sight Template Data
- Easy Generation Of Block Assembly Data
  - Work Instructions
  - 3D Assembly Drawings
  - 'Poka Yoke', 'Egg Crating'

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## E-Business

- Collaboration
  - NIIP SPARS / MAST Pilot Demonstration Success
  - Allows Geographically Dispersed Teams
  - Allows Distant Pre-Outfitting By Specialists
- Connects Prime, Suppliers And Subcontractors
- Two Business Models
  - Better Data Exchange Vs Wider Bidding
- Product Model And Standards – NIIDESC, DWF
- Easy To Implement:
  - Commercial Solutions: RedSpark, Buzzsaw, Etc.
  - Homebuilt - Intranets, Groups, Etc.
  - Yacht Industry Co-op E-Business Group ?

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## Call To Action

- Cooperation
- Training
  - Focussed Peer-To-Peer Training
  - Production Level/Management Level Training
  - Vendors Need To Get To The Check Writer
- Standards
  - High Level Product Modeling Standards
  - Model Viewing Standards For Regulators, Owners
  - Good Vendor Data

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## Resources

- [www.sname.org](http://www.sname.org)
- Journal Of Ship Production
- Ship Production Symposium
- [www. USAShipbuilding.com](http://www.USAShipbuilding.com)
- [www.nsnet.com](http://www.nsnet.com)
- [www.aws.org](http://www.aws.org)
- [www.augi.com](http://www.augi.com)
- <http://pointa.autodesk.com>
- [www.albacorerresearch.com](http://www.albacorerresearch.com)
- [www.proteusengineering.com](http://www.proteusengineering.com)
- [www.lincolnelectric.com](http://www.lincolnelectric.com)
- <http://www.penton.com/>

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